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Utility Of A Modified Paediatric Early Warning Score (PEWS) To Predict Mortality Among Severely Malnourished Children In Usmanu Danfodiyo University Teaching Hospital (UDUTH), Sokoto, Nigeria: A Retrospective Analysis

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Abstract
Introduction: *Paediatric Early Warning Scores (PEWS) are illness severity scores designed to identify children at risk of clinical deterioration to prioritize care from point of admission and during care. They are based on physiological measurements including heart rate (HR), respiratory rate (RR), respiratory effort (RE), use of oxygen, oxygen saturation (SPO_2), capillary refill time (CRT) and level of consciousness (LOC). Recently, a modified score, Response to illness Severity Quantification (RISQ) was designed for children with severe malnutrition (SAM) which is one of the highest contributors to admission mortality.*
Objective: *Retrospective analysis of the score parameters in clinical notes in relation to mortality of SAM cases at UDUTH Sokoto, Nigeria.*
Materials & Methods: *3-year retrospective review of children admitted for SAM. Six criteria (HR, RR, RE, LOC), temperature (T°C) & mid-arm circumference (MAC) with outcome of admission were entered into a proforma. The scores allocated were 0,1, 2 or 4 for each parameter based on the age-related criteria and severity (range of 0 to 24). Mean scores were compared for the outcome (survivors vs non-survivors) using student t-test. Sensitivity test analysis was also done. $p<0.05$ was significance level.*
Results: *Of 159 SAM patients, 94 (59.1%) had complete documentation of score criteria. There was no significant difference between the mean clinical parameters of survivors and non-survivors but when scored according to the RISQ criteria and summed, the mean score was significantly higher for non-survivors vs survivors (6.0 ±3.5 vs 4.0 ±2.2) p= 0.001. Scores of HR, RE & LOC were significantly higher in non-survivors vs survivors (1.0 ±0.9 vs 0.43 ±0.50) p= 0.001; (0.8 ±1.0 vs 0.41 ±0.70) p= 0.03; (0.58 ±1.03 vs 0.06 ±0.32) p= 0.01. A receiver operating characteristic (ROC) curve was generated and total area under the curve (AUC) was 0.66 (95% CI,0.55-0.77; p=0.007). The most optimal cutoff of sensitivity (53.2%) and specificity (75.5%) was a score of 4.5.*
Conclusion: *Early warning scores may be useful in predicting mortality in SAM patients especially HR, respiratory distress & LOC. More studies on defining criteria are needed in Nigerian children.*
Keywords = *PEWS, RISQ, outcome, mortality, severe malnutrition, Sokoto*

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I. Introduction

Severe acute malnutrition affects more than 20 million children worldwide, and it is highly prevalent in the African region, where health systems are poor in capacity while also coping with other highly prevalent infectious and non-infectious diseases.[1] In Nigeria, estimates quote that about two and a half million children are affected, and Sokoto is one of the worst-hit states with almost half of the children being undernourished.[2] Severe Acute Malnutrition (SAM) has an undue high hospital mortality. High mortality rates of 5.8 to 46% have been reported in Africa and tools to help identify high-risk children are needed.[3]

Paediatric Early Warning scores are designed to identify children at increased risk of deterioration by assigning scores based on vital signs and clinical status from admission and throughout hospital stay which then guide interventions using a response algorithm to improve outcomes.[1, 4] These systems have been shown to be effective in high-resource settings and have the potential to improve the care of children in humanitarian and resource-limited settings.[5, 6] Some parameters used in early warning scores include heart rate, systolic blood pressure, capillary refill time, respiratory rate, respiratory effort, oxygen saturation, and oxygen therapy which can be quickly used by the bedside without any laboratory investigations.[7]

Generally, there is paucity of use of early warning scores in African countries including Nigeria which bear the brunt of total child mortality. However, recently in Maiduguri, Nigeria, some authors adapted and validated a modified early warning score in SAM patients, adding some parameters like temperature, consciousness level and mid arm circumference (MAC) for malnourished patients which was termed Responses to Illness Severity Quantification (RISQ).[5] The score was assessed at admission as a form of triage and also while on treatment and before discharge. The RISQ score was found to identify high-risk malnourished children at admission and its application would help improve survival.

Severe acute malnutrition is one of the highest contributors to admission mortality in the paediatric department of UDUTH Sokoto.[8] In another study in UDUTH, limited to the paediatric emergency, SAM accounted for the 5th top cause of admissions and 2nd topmost cause of mortality.[9] Availability of a score that can be easily used by doctors and nurses and serve as a triage on admission would be helpful in reducing the mortality burden of SAM. The objective of this study was to assess the performance of the modified early warning score retrospectively at admission in relation to mortality of SAM cases at UDUTH, Sokoto, Nigeria.

II. Materials And Methods

Study Location

The study was conducted at the UDUTH, Sokoto, a major referral centre for paediatric cases in the extreme north western region of Nigeria. It was conducted as part of a study on clinical profile and outcome of treatment of admitted SAM cases.[10]

Sokoto is located in the dry Sahel region, surrounded by sandy Savannah. It has an annual average temperature of 28.3ºC, which rises to as high as 45.0ºC during the hot dry months. The dry season is longer and comprises the hot dry season before the rains from March to April and the cold, dry season from November to February with a short rainy season from late May till September. Intensive farming activities take place during this raining season period. The inhabitants engage in crop farming and animal husbandry in addition to small to medium-scale business activities. Sokoto state has one of the highest burden of malnutrition in the country according to the Nigerian Demographic and Health Survey 2018.[11]

Study population: Comprised children aged 6 months to 5 years admitted into the EPU with severe acute malnutrition (SAM).

Study period: It was a retrospective study conducted on patients admitted from January 2017 till December 2019

Selection of cases: It was a purposive sampling from 159 SAM patients admitted in that period. They were categorised into survivors and non-survivors. The non-survivors who had sufficient documentation were included. These were 47 out of the total of 159. Consequently, 47 survivors with adequate documentation of relevant criteria were further purposively selected for comparison. They were also matched according to their type of malnutrition (oedematous vs non-oedematous).

Data collection procedure

The vital signs and clinical observations documented on admission were extracted into a proforma. The vital signs extracted included Heart rate (HR), Respiratory rate (RR), Respiratory effort (RE), Temperature (T°C), Level of consciousness (LOC). Mid arm circumference (MAC) was also added though not utilized in the final score by Dale.[5] Oxygen saturation and level of oxygen use could not be used as they were incompletely documented as shown in the table 1 below.

Table 1: Level of Documentation of criteria required for the early warning score

Parameter	Frequency	% documented of 94 cases
Heart rate	**94**	**100%**
Respiratory rate	**94**	**100%**
Temperature	**94**	**100%**
Respiratory effort	**94**	**100%**
Level of consciousness	**94**	**100%**
O_2 saturation	**34**	**36.2%**
O_2 therapy	**17**	**18.1%**
Flow rate for those on O_2 therapy	**0**	**0%**
Capillary refill	**11**	**11.7%**
Systolic blood pressure	**5**	**5.3%**

Scoring of parameters

Among the 6 parameters, heart rate and respiratory rate are age dependent. They reduce with age. The ages were dichotomized into 6 to <12 months and age 1 to 5 years as used by Dale. This was adapted from the scoring system developed by Parshuram[7] where the cut-off points therein were established by reports from systematic review and experts' opinion.[12] The scores allocated were '0', '1', '2' or '4' for each parameter based on the age-related criteria and severity (total range of 0 to 24). Score of "0" did not necessarily imply a normal vital sign but that which is less associated with clinical deterioration. Scores of '1', '2', & '4' represented values of parameters below or above those coded '0'. For example, bradypnea & tachypnea (for respiratory rate) bradycardia & tachycardia (for heart rate), hypothermia & high grade pyrexia (for temparature) & severe wasting (for low MAC) as shown in Table 2.

Outcome of admission was categorized as survivors for those who were discharged vs non-survivors for those who died on admission.

Table 2: Scores Used for Assessing the Parameters (Dale 2022)[5]

Individual item	Age grp (months)	Score			
		0	1	2	4
HR (bpm)	6 to <12	100-150	80-99 or 151-170	70-79 or 171-180	<70 or >180
	12–60	90 – 120	70 -89 or 121 – 150	60 -69 or 151 - 170	< 60 or >170
RR (breath/min)	6 to <12	24 – 50	20 -23 or 51 -70	15 -19 or 71 - 80	< 15 or > 80
	12–60	20 -40	16 -19 or 41 -60	12 -15 or 61 -70	< 12 or > 70
Resp. effort	6–60	Normal	Mild	Moderate	Severe
Temperature (°C)	6–60	≥36–38.5		<36	>38.5
Level of consciousness	6—60	Awake and alert	Response to voice	Response to pain	Unresponsive
MAC (mm)	6–60	>125	115–125	100–114	<100

Data entry and analysis

All relevant data were entered into the SPSS statistical software version 25. Quantitative data like age, weight, height and scores were expressed as means and standard deviation. The mean of scores were compared for each parameter for both groups (survivors vs non-survivors) using student t-test. The scores for each parameter were summed to get a total score which was categorized. Parshuram[7] found a score of '8' discriminated between survivors and non-survivors and this was used initially used to assess the outcome.

Categorical variables like gender and score classification was expressed as proportions. Chi-square or where necessary, Fisher's Exact test, was used to test for statistical significance. Receiver operating characteristic (ROC) was used to test for sensitivity and specificity of the total score in relation to outcome. A p-value of <0.05 was considered statistically significant.

Ethical approval

This was sought and obtained from the ethics and research committee of UDUTH, Sokoto.

III. Results

Socio-demographic characteristics

There were 94 SAM patients comprising 47 survivors and 47 non-survivors. Male to female ratio was 1.54:1 with 57 (60.6%) males and 37 (39.4%) females. The mean age was 20.3 ± 9.9 months with a range of 8 months to 60 months. Majority 69 (73.4%) were aged 13 to 36 months followed by 6 to 12 months accounting for 19 (20.2%). Table 3 shows some socio-demographic characteristics and clinical variables of the study population. The median length of illness was longer among the non-survivors.

Baseline clinical characteristics of the survivors and non-survivors

Table 4 shows comparison of the means of the baseline clinical characteristics of the survivors and non-survivors. There was no significant difference between the all the means of the quantitative variables namely the heart rate, respiratory rate, temperature, mid-arm circumference, occipitofrontal circumference and weight of the survivors and non-survivors. The mean heart rates were similar while the mean respiratory rates & temperature were higher among non-survivors and occipitofrontal was lower in non-survivors. The mean mid-arm circumference and weight were higher amongst non-survivors. However, none attained statistical significance except for mean age that was higher among non-survivors.

Table 3: Socio-demographic demographic variables and clinical characteristics (n=94)

Variable	Frequency (%)			
	Survivors	Non -survivors	Test	Significance
Age category (mo)*				
6 – 12	12 (25.5)	7 (14.9)	$X^2 = 3.9$	0.13
13 - 36	34 (72.3)	35 (74.5)		
37 - 60	1 (2.1)	5 (10.6)		
Gender				
Male	28 (59.6)	29 (61.7)	$X^2 = 0.05$	0.83
Female	19 (40.4)	18 (38.3)		
SAM category				
Non-oedematous	28 (59.6)	28 (59.6)	$X^2 = 0.00$	1.00
Oedematous	19 (40.4)	19 (40.4)		
Duration of illness				
Median, IQR (days)	28, 46	30, 76		

*mo = months

Table 4: Comparison of baseline clinical characteristics of survivors and non-survivors

Variable	Mean values (SD)				
	Survivors	Non -survivors	T-test	Significance	95% C.I
Age (mo)	18.2 (6.6)	22.4 (12.1)	2.10	0.04*	0.20 – 8.20
Weight (kg)	6.3 (1.0)	6.6 (1.5)	0.86	0.39	-0.31-0.77
Height (cm)	74.4 (5.0)	76.6 (9.1)	1.30	0.21	-1.27 – 5.57
HR (bpm)	118.8 (17.6)	118.8 (22.5)	-0.07	0.99	-9.40 - 9.30
RR (cpm)	36.0 (9.3)	39.5 (12.5)	1.34	0.18	-1.70 – 3.60
Temperature (°C)	37.4 (0.93)	37.7 (1.03)	1.5	0.14	-0.11- 0.80
MAC (cm)	10.5 (1.3)	10.8 (1.5)	0.94	0.40	-0.35- 1.01
OFC (cm)	44.2 (2.0)	44.0 (3.1)	-0.24	0.81	-1.81 – 1.43

* = significant; mo = months; HR = heart rate; RR = respiratory rate; MAC = mid arm circumference; OFC = occipitofrontal circumference

Association of mean parameter scores and total scores with mortality

The parameters which had been transformed into scores according to age related criteria have their total scores and mean shown in Table 5. Scores were significantly higher for non -survivors compared to survivors among the SAM patients. The mean for non-survivors 6.0 ±3.5 vs 4.0 ±2.2 (p= 0.001) Table 5. For the individual parameters of HR, RE & LOC, scores were significantly higher in non -survivors vs survivors. The mean score for HR for non-survivors was 1.0 ±0.9 vs 0.43 ±0.50 among those that survived (p= 0.001). Mean score for RE was 0.8 ±1.0 in non-survivors while for the survivors it was 0.41 ±0.70 (p= 0.03). Similar trend was seen for LOC with 0.58 ±1.03 in non-survivors while it was 0.06 ±0.32 in survivors (p= 0.01).

The MAC, RR, and T°C scores were higher among the non-survivors but did not attain statistical significance as shown.

Table 5: Comparing Mean Scores of Non -Survivors and Survivors of SAM

Parameter	Mean Scores (SD)				
	Survivors	Non -survivors	T-test	p-value	95% C.I
Total score	4.02 (2.24)	6.04 (3.52)	3.3	0.001*	0.82-3.22
HR score	0.43 (0.50)	1.02 (0.90)	4.0	0.001*	0.30-0.88
RR score	0.40 (0.57)	0.60 (0.65)	1.68	0.05	0.03 - 9.9
Resp. Effort score	0.41 (0.7)	0.8 (1.01)	2.2	0.031*	0.04 - 0.75
Temperature score	0.73 (0.76)	1.0 (0.9)	1.6	0.1	-0.07 - 0.82
LOC score	0.06 (0.31)	0.58 (1.03)	3.3	0.001*	0.20 - 0.82
MAC score	2.00 (1.24)	2.06 (1.25)	0.26	0.80	-0.44 - 0.57

* = significant; HR = heart rate; RR = respiratory rate; MAC = mid arm circumference; LOC =level of consciousness

Association between score category and mortality

A total score higher than eight discriminated the survivors better than non-survivors. $X^2 = 5.4$, p = 0.02, df = 1 as shown in Table 6. Majority of survivors (44 out of 47; 95.7%) had total score less than 8. Of those with score above 8, who were 14 in number, majority were non-survivors (23.4% vs 4.3%).

Table 6: Association Between Score Category and Outcome

Score category	Non-survivors n (%)	Survivors n (%)	Total n (%)
≥ 8	**11 (23.4)**	3 (4.3)	14 (100)
< 8	36 (76.6)	44 (95.7)	80 (100)
Total	**47 (100)**	**47 (100)**	**94 (100)**
$X^2 = 5.4$, p = 0.02			

Receiver operating characteristics and area under curve testing for sensitivity and specificity

A receiver operating characteristic curve was generated and total area under the curve was 0.66 (95% CI,0.55-0.77; p=0.007). The most optimal cutoff of sensitivity and -1 specificity was a score of 4.5 with sensitivity of 53.2% and specificity of 75%. The positive predictive value was 67.6% while the negative predictive value was 61.4%.

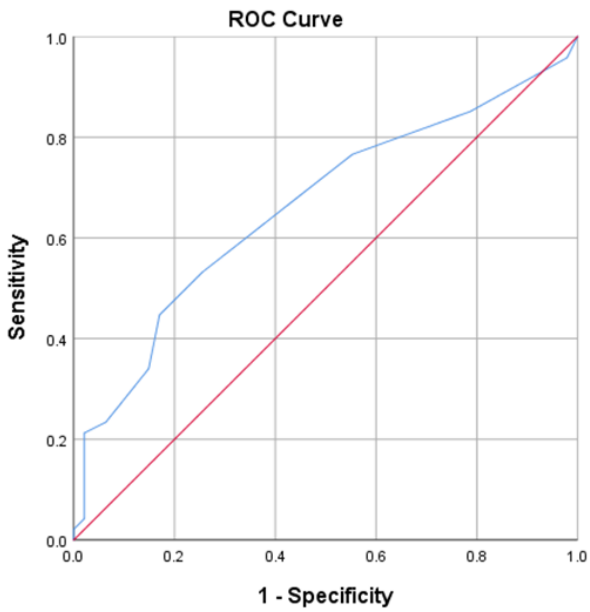

Figure 1: Receiver Operating Characteristics & Area under the Curve

With a cut-off score of 4.5, the sensitivity increased to 53.2% while the specificity dropped to 74.5% (Table 7)

Table 7: Association Between Score Category and Outcome

Score category	Non-survivors n (%)	Survivors n (%)	Total n (%)
≥ 4.5	25 (53.2) **TP**	12 (25.5) **FP**	37 (100)
< 4.5	22 (46.8) **FN**	35 (74.5) **TN**	57 (100)
Total	**47 (100)**	**47 (100)**	**94 (100)**
X^2 = 7.5, p = 0.006, df = 1			

TP=True positive; FP=False positive; FN=False negative; TN=True negative

IV. Discussion

In this study, score parameters used in a previous study was retrospectively assessed for utility in a cohort of SAM patients admitted over 2 years. There was a 45.8% mortality rate among the 159 SAM patients seen over that period which was similar to the rates seen in some studies in developing countries among similar patients.[13] This could probably due to their severity as occurs with reduced adaptation from poor nutrient intake, slow metabolism and inability to withstand rapid resuscitation.[14] Mortality rate in these children could be due to lack of requisite experimental studies before the development of the treatment protocol in a study by Amodu-Sani et al.[14]

Of the 159 patients, only 59.1% had documentation of relevant criteria. Other score parameters that could be used including capillary refill time, blood pressure, pulse oxygen saturation, oxygen requirement and flow rate were incompletely documented or even absent in some cases. Kowalski[15] also highlighted this finding in their retrospective analysis of scores in patient's prior to transfer to the critical care unit where they found that more than 20% of cases did not have parameters for scores recorded while Chapman[16] found that only 36% of their sample had adequate vital signs documented to calculate a PEWS score. This also brings to fore problems of poor documentation practices especially with paper based formats that still predominate in this environment.[17]

Variables used in the study were heart rate, respiratory rate, respiratory effort, level of consciousness, temperature, and mid arm circumference due to the non-recording of capillary refill time, blood pressure and oxygen use. One striking finding was that when the mean of some of the quantitative variables used in the scores, were calculated as their real values there was no significant difference between the survivors and non-survivors except for age. However, when converted to scores, there was significant differences between the scores of those variables, highlighting clinical relevance of score categories. The score parameters that were significantly higher amongst the non-survivors were heart rate, respiratory effort and level of consciousness. Respiratory rate, temperature and MAC were also higher among the non-survivors but did not attain statistical significance.

The non-discriminatory effect of MAC could be explained by the fact that it is a criterion of diagnosis of SAM unlike the other parameters so it would be comparable in all malnourished patients. In Dale's study, MAC did not also discriminate between the survivors and non-survivors.[5] Also, it was opined by Dale[5] that MAC in malnourished patients portends more of long term risk of mortality rather than acute risk of mortality. In a study carried out in Malawi and Kenya by Wen et al[18] on clinical warning signs of mortality in malnourished patients, MAC was dichotomized into severe and non-severe wasting (<10.5cm vs ≥10.5cm) before the discriminatory effect was evident unlike in this study and Dales[5] where it was categorized into 4 groups.

Scores of heart rate, respiratory effort and level of consciousness were more significant in this study possibly due to the fact that they may represent features of multiorgan dysfunction of the respiratory, cardiac and central nervous systems unlike mid-arm circumference.[19] Similarly, the items assessed at admission with the strongest associations with mortality were respiratory effort, oxygen use and level of consciousness in Dale's study.[5] Reduced consciousness and chest indrawing were also among independent predictors of mortality reported by Wen.[18]

Admission scores were calculated from all the parameters retrospectively in this study as a baseline which showed mean scores were higher in the non-survivors (6.02) than survivors (4.02). This is similar to reports by Dale[5] in Maiduguri where score of 7.3 vs 2.6 was gotten in the 2 categories. Cut-off values for action and escalation of care differs in different settings based on the parameters used.[20] Scores were categorized initially as (< 8 and ≥8) as scores ≥ 8 were associated with higher mortality in the report by Parshuram.[7] However, use of < 8 and ≥8 in this study as cut-off could only discriminate more among the survivors ie specificity of 94.5% with a very low sensitivity of 23.4%.

The sensitivity was 53.2% with specificity of 75% at a score of 4.5 with (area under receiver operating characteristic) AUROC of 0.66. The sensitivity was lower than the specificity meaning that the rate of identification of those at risk of mortality was low. Phuaksaman[21] opined that for optimal discrimination, the early warning score should be highly sensitive while also having a high AUROC and positive and negative predictive values. This was not observed in this study and could be attributed to the small sample size and inclusion of temperature and MAC which were not significantly different between the survivors and non-survivors. Different studies had somewhat similar cutoff points but with higher sensitivity and specificity. The sensitivity was 78% and the specificity was 95% at a score of 5 in a study by Duncan.[22] Agulnik[23] reported sensitivity of 88%, specificity of 93% for a PEWS score of 5 and AUROC of 0.94 predicted intensive care management while Olson with a modified score called inpatient triage, assessment and treatment showed it was associated with mortality with an AUROC of 0.76, sensitivity of 44% and specificity of 86%.[24] Doyle[25] also found a score of 4 and above as a trigger for action with 75% sensitivity and 83% specificity for predicting which patients required transfer to a higher level of care. Ye Cheng[26] while evaluating the Brighton PEWS in 4717 patients had differing scores but 4.5 predicted mortality at 72.2% sensitivity and 79%, specificity.

V. Conclusion

Modified PEWS especially items scores of HR, respiratory distress & LOC may be useful in predicting mortality and escalating care in SAM patients and other critically ill children in our health facilities in this environment. However, these should not override clinical judgement and clinicians should still recognize signs of deterioration without early warning scores.

VI. Limitations

There was inability to utilize some score parameters due to lack of assessment and documentation.

VII. Recommendations

Further studies on PEWS and RISQ scores utility in paediatric emergency care are required. Ensuring assessment and documentation of vital signs such as capillary refill time (CRT) & BP while also appropriately prescribing & documenting O_2 therapy and flow rates in case notes.

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